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## SMALL MAMMALS OF SANGAY NATIONAL PARK, CHIMBORAZO PROVINCE AND MORONA SANTIAGO PROVINCE, ECUADOR

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### ABSTRACT

In 2010 a mammal survey was conducted in an ecotone region (including páramo and temperate forest) on the eastern slope of the Andes in Sangay National Park, Ecuador. Sherman traps, Tomahawk traps, pitfall traps, and mist nets were used to collect mammal specimens at two sites (3,400 m elevation and 2,962 m elevation). A total of 169 specimens representing 14 species were collected from the survey area. The species collected include: *Caenolestes caniventer*, *Cryptotis montivaga*, *Akodon mollis*, *Microryzomys altissimus*, *M. minutus*, *Thomasomys praetor*, *T. baeops*, *T. cinnameus*, *T. paramorum*, *T. silvestris*, *Sturnira bidens*, *S. erythromos*, *Micronycteris megalotis*, and *Myotis keaysi*. One additional species (*Mazama rufina*) was recorded photographically. In addition, a new national record of a parasitic beetle (*Amblyopinus colombiae*) was discovered on a specimen of *T. praetor*.

Key words: Chimborazo, distribution range, Ecuador, mammals, Morona Santiago, Sangay National Park

### RESUMEN

En el año 2010 se llevó a cabo un inventario de mamíferos en una región de ecotono (que incluye páramo y bosque templado) en el Parque Nacional Sangay en las estribaciones orientales de los Andes del Ecuador. Se usaron trampas Sherman, Tomahawk, pitfall, y redes de neblina para coleccionar especímenes de mamíferos en los dos sitios de estudio (a elevaciones entre 2,962 y 3,400 msnm). Un total de 169 especímenes de 14 especies fueron colectados en el área de estudio. Las especies colectadas incluyen: *Caenolestes caniventer*, *Cryptotis montivaga*, *Akodon mollis*, *Microryzomys altissimus*, *M. minutus*, *Thomasomys praetor*, *T. baeops*, *T. cinnameus*, *T. paramorum*, *T. silvestris*, *Sturnira bidens*, *S. erythromos*, *Micronycteris megalotis*, y *Myotis keaysi*. Una especie adicional (*Mazama rufina*) fue registrada fotográficamente. Un nuevo registro nacional de escarabajo parásito (*Amblyopinus colombiae*) fue descubierto en un espécimen de *T. praetor*.

Palabras clave: Chimborazo, Ecuador, mamíferos, Morona Santiago, Parque Nacional Sangay, rango de vida

## INTRODUCTION

The purpose of this study was to document the small mammal assemblage of Parque Nacional Sangay in south central Ecuador. Ecuador has had a long history of mammalian surveys beginning in the early 1900s (e.g., Stone 1914; Allen 1916; Anthony 1924a, 1924b; Tate 1931; Barnett 1999; Lee et al. 2006a, 2006b, 2008, 2010; McDonough et al. 2011). Other studies conducted in the same region and elevation as Parque Nacional Sangay include surveys of Cajas Plateau and the corridor between Sangay and Llanganates National Parks (Barnett 1999; Haynie et al. 2006).

This survey is important because park officials wanted to know what species of small mammals occurred in Parque Nacional Sangay. The long-term goal of this project and related studies is to acquire comparative material to facilitate studies of the biogeography, ecology, and evolution of mammals in Ecuador (Jarrín and Fonseca 2001; Lee et al. 2006a, 2006b, 2008, 2010).

## STUDY AREA AND METHODS

This study was conducted from 21 July to 11 August 2010 at two sites (3,400 m and 2,962 m elevation) in the eastern páramo and temperate forests, respectively, in Parque Nacional Sangay, which is located on the border between Chimborazo and Morona Santiago Provinces on the eastern slope of the Andes. The study area includes mountain lakes, called the Atillo Lagoons, and their associated marshes and *Polylepis* forests. The páramo and temperate forests of eastern Ecuador are characterized by high rodent diversity and low bat diversity as compared to other similarly sampled areas (Lee et al. 2006a, 2006b, 2008, 2010). The study sites therefore were chosen because of the lack of documented mammals in Parque Nacional Sangay and to investigate differences in mammalian diversity due to changes in elevation within a small area (Patterson et al. 1996).

Two locations, 4.69 km apart, were surveyed during this study, one near the Atillo Lagoons and another within the drainage of the Río Upano (Fig. 1). Site 1, at 3,400 m elevation, includes a series of trap locations near the Atillo Lagoons, a basin of lakes surrounded by mountains that are between 3,900 and 4,200 m high (2°11'33.4"S, 78°31'29.38"W to 2°10'55.99"S, 78°29'57.36"W). We collected at these locations from 21 July to 11 August 2010 (21 days). The habitat is primarily alpine grassland dominated by *Stipa ichu* (Poaceae) with patches of *Polylepis* forests. Other plant families that we identified in this habitat were: Asteraceae, Bromeliaceae (*Puya*), Calceolariaceae,

Passifloraceae, Fabaceae, Onagraceae, Orchidaceae, Polypodiaceae (ferns), and Valerianaceae. In places where the soil is not well drained, *Sphagnum* moss is abundant. Stands of reed in the family Cyperaceae were observed in the lagoons.

Site 2 is southeast of Site 1, in Morona Santiago Province, at 2,962 m elevation (2°12'17.87"S, 78°27'30.92"W) (Fig. 1). This site was sampled for 16 days from 25 July to 9 August 2010. This area consisted of secondary forests and a riparian habitat on the Río Upano. Most of the traps and nets were set near the edge of the secondary growth managed forest and a riparian forest. At this site the plant families Astroseriaceae, Bromeliaceae, Clusiaceae, and Poaceae also were noted along the stream banks. For both sites, identification of plant families was conducted using Patzelt (2004), and photos of plants from the sites were examined by Ken Sytsma (Department of Botany, University of Wisconsin) for confirmation.

Five Tomahawk and 170 Sherman traps were set in the grasslands, on the forest floor, in trees, in streams, and on stream banks for 3,675 trap-nights. Bats were caught with four, 9-18 m long mist nets set in or near riparian habitat at the 2,962 site (192 net-hours). Pitfall traps were set in forests and along stream banks and logs. All voucher specimens (skins, skulls, skeletons, and frozen liver tissue) were deposited in the Abilene Christian University Natural History Collection (ACUNHC) and at the Museo de Zoología (QCAZ),

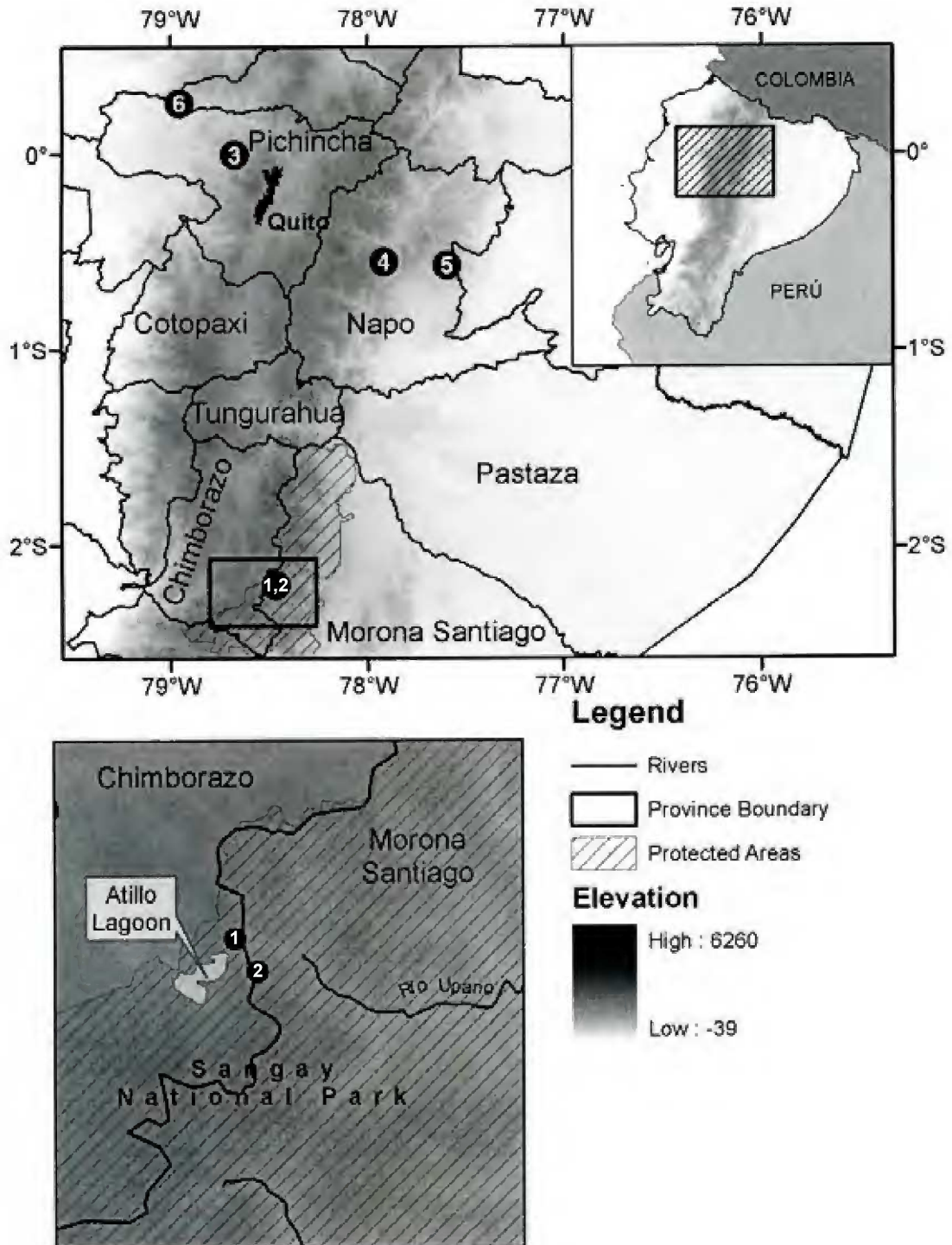


Figure 1. The location of the study sites in Parque Nacional Sangay are designated by the numbers 1 (3,400 m elevation) and 2 (2,962 m elevation) (also see inset map). The other study sites used for comparison are: location 3, the Tandayapa Valley ( $0^{\circ}00'13''N$ ,  $78^{\circ}40'70''W$ ); location 4, the Casanga River Valley sites ( $0^{\circ}33'00''S$ ,  $77^{\circ}55'00''W$  and  $0^{\circ}31'70''S$ ,  $77^{\circ}52'99''W$ ); location 5, the eastern slope of Volcán Sumaco ( $0^{\circ}34'19''S$ ,  $77^{\circ}35'64''W$ ); and location 6, the Santa Rosa sites ( $0^{\circ}19'51''N$ ,  $78^{\circ}55'55''W$  and  $0^{\circ}17'33''N$ ,  $78^{\circ}57'38''W$ ).

Sección de Mastozoología at Pontificia Universidad Católica del Ecuador. Specimens were treated in accordance with the guidelines of the American Society of Mammalogists for the use of wild mammals in research (Sikes 2011).

Voucher specimens from this study were compared with specimens in the collections of Abilene Christian University Natural History Collection, American Museum of Natural History, and Museo de Zoología, Sección de Mastozoología, Pontificia Universidad Católica del Ecuador to confirm species identity. Some specimens of questionable identification were examined by other researchers, named in Acknowledgments, to further corroborate species identifications. Nomenclature used in this study follows Wilson and Reeder (2005) for marsupials, shrews, deer, and rodents, except for the Oryzomyine rodents,

which follows Weksler et al. (2006), and for bats, which follows Gardner (2007). Some taxonomic identifications were further corroborated by sequencing the cytochrome-*b* gene using previously published methods (Hanson and Bradley 2008). The specimens that were sequenced include: *Akodon mollis* (ACUNHC 1578, 1581, 1583, 1585, 1587, 1588, 1591, 1595, 1596, 1602, 1603); *Thomasomys baeops* (ACUNHC 1598); *T. cinnameus* (ACUNHC 1582); *T. paramorum* (ACUNHC 1600); *T. praetor* (ACUNHC 1560); and *T. silvestris* (ACUNHC 1592). The sequences were then compared to sequences deposited on GenBank using a neighbor-joining tree (Kimura 2-parameter; Kimura 1980).

A Shannon Index value (Shannon 1948) was calculated for each site and compared to diversity values from similar studies (Jarrín and Fonseca 2001; Lee et al. 2006a, 2006b, 2008, 2010).

## RESULTS

In total, 169 specimens of 14 species of small mammals were collected. An additional species, *Mazama rufina*, was photographed at the 3,400 m site. Ten species were collected at the 2,962 m site and ten species were collected or observed at the 3,400 m site (Table 1). No bat species were captured or observed at the 3,400 m site. Five rodent species, *Akodon mollis*, *Microroryzomys minutus*, *Thomasomys baeops*, *T. cinnameus*, and *T. silvestris*, were documented from both locations. Four of the species collected represent new records for Parque Nacional Sangay (Casto and Jácome 1999).

ORDER PAUCITUBERCULATA  
Family Caenolestidae  
*Caenolestes caniventer* Anthony 1921  
Gray-bellied Caenolestid

Eight specimens, all males (ACUNHC 1550, 1551, 1552, 1555, QCAZ 11871, 11875, 11876, 11877), were collected in Sherman traps set in a mixture of secondary growth and primary growth riparian temperate forest at the 2,962 m site. Two specimens were caught in a trap next to a hole under a tree. Our largest adult specimen is larger (head and body length 129 mm) than those reported by Timm and Patterson (2007). The rest of our specimens appear to be subadults and are

smaller in size (head and body 99 to 113 mm). These specimens have an antorbital vacuity that is comma-shaped and bounded by nasal, maxillary, and frontal bones. Furthermore, the palatal bridge is curved, which is diagnostic for *Caenolestes caniventer* (Timm and Patterson 2007). The dorsal color is a grizzled grayish brown. There is no conspicuous pectoral spot as reported by Timm and Patterson (2007). The ventral fur is gray to cream with a dark gray base. The conspicuous gray ears are lightly furred and have a lighter colored margin. These specimens represent the first record for Morona Santiago (Tirira 2007). Previously reported locations are in western Azuay, Cañar, Chimborazo, Pichincha, El Oro, Loja, and Zamora Chinchipe Provinces (Anthony 1921; Bublitz 1987; Albuja and Patterson 1996; Brown 2004; Tirira 2007). For basic measurements see Table 1.

ORDER SORICOMORPHA  
Family Soricidae  
*Cryptotis montivaga* (Anthony 1921)  
Wandering Small-eared Shrew

One male (QCAZ 12037) was captured at 3,400 m in Chimborazo Province. The species was identified by the presence of silver/gray pelage. This specimen was collected in habitat described by Barnett (1999) as

Table 1. Presented are range status, collecting site, and measurements (mm) of mammal specimens collected in or near Parque Nacional Sangay, Ecuador. Range designations are as follows: R = major range records (species not previously recorded in Parque Nacional Sangay or within 70 km of the study sites); E = an elevation distribution record for the eastern Ecuadorean Andes; Known = species previously documented from Parque Nacional Sangay. Site 1 is the 3,400 m site; site 2 is the 2,962 m site.

Species	Range	Site	Total length	Tail length	Hind foot	Ear	Forearm length
<i>Caenolestes caniventer</i>	R	2	206-261	114-132	22-28	12-18	N/A
<i>Cryptotis montivaga</i>	Known	1	122	33	17	0	N/A
<i>Micronycteris megalotis</i>	E	2	75	19	11	16	33.2
<i>Sturnira bidens</i>	Known	2	66-70	0	12-16	13-16	41.8-44
<i>Sturnira erythromos</i>	Known	2	68	0	15	15	42
<i>Myotis keaysi</i>	E	2	91-101	42-49	9-10	13-15	41.6-42
<i>Akodon mollis</i>	Known	1 and 2	163-208	57-98	15-27	14-20	N/A
<i>Microroryzomys altissimus</i>	Known	1	191-196	108-117	24-25	15-16	N/A
<i>Microroryzomys minutus</i>	Known	1 and 2	179-205	108-130	17-25	15-16	N/A
<i>Thomasomys praetor</i>	R	1	376-432	211-249	38-42	24-25	N/A
<i>Thomasomys baeops</i>	Known	1 and 2	224-242	117-137	18-26	15-19	N/A
<i>Thomasomys cinnamomeus</i>	R	1 and 2	163-205	84-125	19-25	13-17	N/A
<i>Thomasomys paramorum</i>	Known	1	207-247	113-145	21-27	16-19	N/A
<i>Thomasomys silvestris</i>	R	1 and 2	233-288	121-166	26-34	17-25	N/A
<i>Mazama rufina</i>	Known	1	N/A	N/A	N/A	N/A	N/A

quenoa forests dominated by *Polylepis*. Our specimen was collected at the base of a cliff with water-logged soils and the ground vegetation was primarily moss and grasses. This specimen was found well within its range (Tirira 2007).

#### ORDER CHIROPTERA

##### Family Phyllostomidae

##### *Micronycteris megalotis* (Gray 1842)

##### Little Big-eared Bat

One male (QCAZ 12030) was collected at 2,962 m. This specimen represents a slight elevation record from the previous record of 2,950 m in eastern Ecuador

(Castro and Román 2000; Carrera 2003; Tirira 2007, 2008), although they are found at higher elevations in other regions (Patterson et al. 1996). The pelage is 8-10 mm long and the body length is less than 55 mm (Simmons and Voss 1998). These characters separate this species from other *Micronycteris*. For basic measurements see Table 1.

##### *Sturnira bidens* Thomas 1915

##### Andean Yellow-shouldered Bat

Five specimens, all males (ACUNHC 1565, 1566, QCAZ 12032, 12033, 12034), were collected at 2,962 m. This species can be distinguished by two lower inci-

sors instead of the typical four for the genus (Giannini and Barquez 2003). These specimens were found well within the documented range (Tirira 2007; Gardner 2007). For basic measurements see Table 1.

***Sturnira erythromos*** (Tschudi 1844)  
Hairy Yellow-shouldered Bat

A single male (QCAZ 12036) was collected at 2,962 m. The specimen had a forearm of 42 mm and was all gray in color with no shoulder spots. These characters indicate that it is a *Sturnira erythromos* (Giannini and Barquez 2003). This specimen was found well within the documented range for the species (Tirira 2007; Gardner 2007). For basic measurements see Table 1.

Family Vespertilionidae  
***Myotis keaysi*** Allen 1914  
Hairy-legged Myotis

One male and two females (ACUNHC 1561, QCAZ 12038, 12040) were collected from 2,962 m. These specimens represent a slight elevation record for the species in Ecuador from the recorded range of 2,950 m (Tirira 2007). They are found higher in other regions (Patterson et al. 1996). The diagnostic characters of these specimens are that they have a sagittal crest, the upper premolar is in the tooth row, and the distance between C1 and C1 is more than the postorbital constriction (Moratelli and Wilson 2011). One individual had a single embryo. For basic measurements see Table 1.

ORDER ARTIODACTYLA  
Family Cervidae  
***Mazama rufina*** (Pucheran 1851)  
Ecuador Red Brocket

The occurrence of *Mazama rufina* was documented with photographs. The animal was found at the 3,400 m site standing near a house owned by the national park in a habitat dominated by *Polylepis* trees. The animal's height was approximately 400 mm at the shoulders, based on the measurements of objects near where the deer was standing in the photos. Identification of the animal was consistent with descriptions

given by Hershkovitz (1982). This animal had a black face with a white mental patch and a white narial patch. The buccal patch or lower cheek was dark red. The inside of the ears are mostly black with white hair interspersed (Barrio 2010). The posterior side of the neck was black, with most of the body dark red with black legs. The only other sympatric deer of similar size is *Pudu mephistophiles*. Pudu have a completely black face with no white in the mental or narial patches and no red on the buccal patch (Hershkovitz 1982). Both *P. mephistophiles* and *M. rufina* previously have been documented in Parque Nacional Sangay (Tirira 2007).

ORDER RODENTIA  
Family Cricetidae  
***Akodon mollis*** Thomas 1894  
Soft-furred Akodont

Fifty specimens (31 males and 19 females, ACUNHC 1575, 1576, 1577, 1578, 1579, 1580, 1581, 1583, 1584, 1585, 1586, 1587, 1588, 1591, 1595, 1596, 1602, 1603, 1604, 1616, 1618-1620, 1628 QCAZ 11879, 11881, 11888, 11889, 11894, 11895, 11902, 11904, 11905, 11907, 11908, 11909, 11913, 11914, 11915, 11917, 11918, 11919, 11921, 11922, 11923, 11924, 11925, 11926, 11927, 11928), were collected from both sites. In the lagoon, páramo, and elfin forest habitats at the 3,400 m site we collected 25 males and 16 females, and in the swampy, cloud forest habitats at the 2,962 m site we collected 6 males and 3 females.

The two collecting sites are 4.69 km apart. Cytochrome-*b* was sequenced for representatives from both populations and revealed a sequence divergence of 1.88% (Alvarado pers. comm.). This value is consistent within most intraspecific divergence and population level variation as assessed by Baker and Bradley (2006). The populations differ in coloration as well. *Akodon* from the 3,400 m site have an overall brown dorsum with each hair having black and yellow banding, and the hair on the dorsum of the feet is white. Specimens from the 2,962 m site have a dark brown (almost black) dorsum and have black hair on the dorsum of the feet. Two females had one embryo each. These specimens were found well within the documented range for the species (Tirira 2007). For basic measurements see Table 1.

*Microrhynchomys altissimus* (Osgood 1933)  
Páramo Colilargo

Two males (QCAZ 11929, 11930) were collected at the 3,400 m site. The incisor tubercle of these specimens was short and indistinct, which separates this species from *M. minutus* (Carleton and Musser 1989). These specimens were found well within the documented range (Carleton and Musser 1989; Tirira 2007). For basic measurements see Table 1.

*Microrhynchomys minutus* (Tomes 1860)  
Montane Colilargo

Six specimens, five males and one female (ACUNHC 1605, 1556, QCAZ 11932, 11933, 11934, 11936), were collected at both the 3,400 m site and the 2,962 m site. These specimens can be distinguished from *M. altissimus* by a tail length of  $\geq 145\%$  of head and body length and by a maxillary toothrow length of  $< 3$  mm (Carleton and Musser 1989). These specimens were found well within the documented range (Carleton and Musser 1989; Tirira 2007). For basic measurements see Table 1.

*Thomasomys baeops* Osgood 1914  
Long-tailed Thomasomys

Nine specimens, six males and three females (ACUNHC 1570, 1594, 1598, 1609, 1614, QCAZ 11945, 11946, 11947, 11948), were collected from both the 3,400 m and 2,962 m sites. The identification was confirmed by Robert Voss and characters presented by Voss (2003). These characters include: length of hind foot  $< 25$  mm; auditory bullae small and uninflated; and maxillary molar row  $\geq 4.2$  mm (Voss 2003). However, analysis of cytochrome-*b* indicates that one specimen (ACUNHC 1598) identified morphologically as *T. baeops* would correspond to another unknown taxa (Fig. 2). Additional investigation is needed to resolve this dilemma. The specimens were found well within the range of *T. baeops* in Ecuador (Tirira 2007). One female had three embryos. For basic measurements see Table 1.

*Thomasomys cinnameus* Anthony 1924  
Cinnamon-colored Thomasomys

Seventeen specimens, 12 males and 5 females (ACUNHC 1564, 1582, 1601, 1610, 1611, 1621, 1627, QCAZ 11970, 11971, 11972, 11973, 11975, 11979, 11981, 11982, 11983), were collected from both the 3,400 m and 2,962 m sites. The morphological identification was confirmed by sequencing cytochrome-*b* (Hanson and Bradley 2008). These specimens represent the first record for Chimborazo and Morona Santiago Provinces. Previous records are from Pichincha, Tungurahua, and Carchi Provinces (Voss 2003; Tirira 2007). These specimens were collected in a variety of habitats, including elfin forest, bogs, and swampy, cloud forest. For basic measurements see Table 1.

*Thomasomys paramorum* Thomas 1898  
Páramo Thomasomys

Forty-four specimens, 22 males and 22 females (ACUNHC 1549, 1558, 1568, 1569, 1574, 1589, 1590, 1593, 1597, 1599, 1600, 1606, 1607, 1608, 1612, 1613, 1615, 1622-1626, QCAZ 11995, 12002, 12004, 12006, 12007, 12008, 12009, 12010, 12011, 12013, 12014, 12015, 12016, 12017, 12018, 12019, 12020, 12021, 12022, 12023, 12024, 12026, 12027, 12028), were collected from the 3,400 m site. All specimens had large inflated auditory bullae, which distinguishes them from other sympatric *Thomasomys* (Voss 2003). Some of these specimens were larger than the measurement range presented by Voss (2003). For example, specimens in this study had tail lengths of up to 145 mm and hind foot lengths of up to 27 mm, whereas Voss (2003) reported 133 mm for maximum tail length and 25 mm for maximum hind foot length. Most of our specimens were collected in *Polylepis* forests near the lagoons and páramo, similar to the habitat that Voss (2003) and Stone (1914) describe for this species. These specimens were found well within the documented range (Tirira 2007). For basic measurements see Table 1.

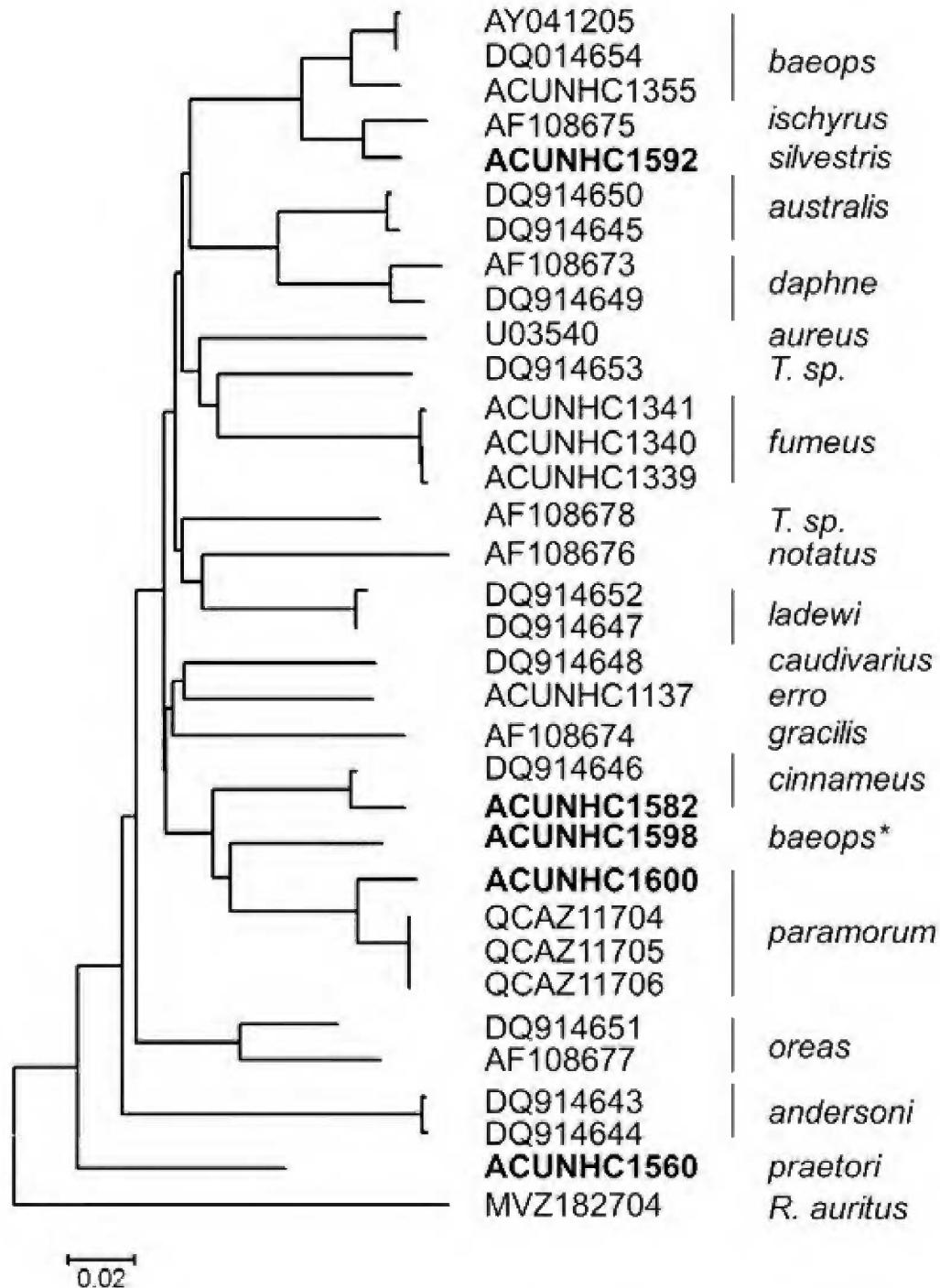


Figure 2. Kimura 2-parameter neighbor-joining tree of *Thomasomys* species based on cytochrome-*b* gene sequences. Abilene Christian University Natural History Collections (ACUNHC) and Sección de Mastozoología, Museo de Zoología, Pontificia Universidad Católica del Ecuador (QCAZ) numbers are listed for specimens collected in Ecuador. Other specimens are listed by their GenBank numbers. *Thomasomys* species names are listed to the right of the figure. Samples listed from Sangay are in bold, and the *Thomasomys baeops* from Sangay (ACUNHC1598) is labeled with an asterisk (\*) and shown sister to a clade containing *Thomasomys paramorum*. The outgroup is a *Reithrodon auritus* deposited at the Museum of Vertebrate Zoology (MVZ).



*Thomasomys praetor* (Thomas 1900)  
Cajamarca Thomasomys

Four specimens, two males and two females (ACUNHC 1548, 1560, QCAZ 11937, 11938), were collected from the 3,400 m site. These specimens were caught near cliff faces and near the páramo temperate forest ecotone. While Cabrera (1961) indicated that *T. praetor* is conspecific with *T. aureus*, Voss (2003) suggested that 4 or possibly 5 distinct species, including *T. aureus* and *T. praetor*, may represent this complex. Although the fur color of our specimens does not match that presented in Voss (2003) for *T. praetor*, sequencing of the cytochrome-*b* gene confirmed that our specimens are *T. praetor* and not the morphologically similar *T. aureus*. Interestingly, the neighbor-joining tree resulting from the cytochrome-*b* data indicates that *T. aureus* and *T. praetor* are not sister taxa (Fig. 2). Clearly, further investigation is warranted to resolve the taxonomy of the species within this complex. These specimens confirm the presence of *T. praetor* in Ecuador (Musser and Carleton 2005). For basic measurements see Table 1.

Two female rove beetles (Coleoptera: Staphylinidae) were discovered on the neck of voucher specimen QCAZ 11938. The beetles were tentatively identified by Michael S. Engel (University of Kansas) as *Amblyopinus colombiae* Seevers 1955, a species first col-

lected from *Thomasomys aureus nicefori* in Antioquia, Colombia (Seevers 1955). The species identification must be considered tentative as the males possess the most diagnostic characters in *Amblyopinus* (M.S. Engel, pers. comm.). If confirmed, this would be the first record of *A. colombiae* from Ecuador.

*Thomasomys silvestris* Anthony 1924  
Sylvan Thomasomys

Nineteen specimens, nine males and ten females (ACUNHC 1554, 1557, 1562, 1563, 1567, 1572, 1573, 1592, 1617, QCAZ 11952, 11955-11957, 11960, 11961, 11963, 11964, 11965, 11966, 11967), were collected from both the 3,400 m and 2,962 m sites. Our specimens are similar in color to those reported by Anthony (1924a). The dorsal hairs are slate gray but tipped with dark brown, giving an overall brown appearance to the dorsum. The ventral fur color is warm light brown at the tip with a bluish gray shaft and base. Most of our specimens have a patch of light brown behind the ears. These specimens represent the most southern record for Ecuador and the first record for Chimborazo and Morona Santiago Provinces. Previous records were from Pichincha and Napo Provinces (Pacheco 2003; Voss 2003). For basic measurements see Table 1.

## DISCUSSION

The mammalian species diversity and richness documented for Parque Nacional Sangay can be compared with the results of five previously published studies in Ecuador (Jarrín and Fonseca 2001; Lee et al. 2006a, 2006b, 2008, 2010) (Table 2). Shannon values for each study, presented in Table 2, are useful for comparing samples where a common species could cause species richness values to be misleading and for comparing the evenness of diversity (Bacaro et al. 2011). Identification of these patterns in species diversity is important in conservation efforts (Bacaro et al. 2011).

A comparison of overall species diversity between this study and previously published data shows a strong trend of decreasing species diversity and rich-

ness with increasing elevation (Patterson 1996; Lee et al. 2006a, 2006b, 2008, 2010) (Table 2). By taxon, bat diversity clearly follows this pattern and probably accounts for the trend in the overall mammalian diversity. This study resulted in the lowest diversity of bats (four species) compared with the other published studies and reflects this trend of low bat species diversity and richness with increasing elevation (Patterson et al. 1996) (Table 2). The numbers of individuals of bats also were very low compared with other surveys. However, some taxonomic groups, such as the cricetid rodents, do not show a pattern of decreasing diversity with increasing elevation. For example, in comparing the results from Santa Rosa (lowest elevation 450 m) and Parque Nacional Sangay (highest elevation 3,400 m), eight species of rodents were collected at each site

Table 2. Comparison of Chiropteran and overall mammalian species composition between this study and previously published studies in Ecuador.

Location	Elevation	Number of bat species	H <sup>p</sup> for bats	Number for all species of mammals	H <sup>p</sup> for all mammals
Imbabura (Lee et al. 2010)	450 m	17	1.10	23	1.23
Imbabura (Lee et al. 2010)	702 m	10	0.86	15	1.03
Imbabura (Lee et al. 2010)	450-702 m	22	1.19	32	1.31
Otonga (Jarrín and Fonseca 2001)	1,300-2,300 m	18	1.02	N/A	N/A
Tandayapa (Lee et al. 2006b)	1,500-2,100 m	13	0.88	19	0.99
Guajalito (Jarrín and Fonseca 2001)	1,800-2,000 m	16	1.03	N/A	N/A
Cosanga (Lee et al. 2006c)	1,900-2,100 m	15	0.82	20	0.91
Volcán Sumaco (Lee et al. 2008)	2,500 m	8	0.58	12	0.84
Sangay National Park (this study)	2,962 m	4	0.50	10	0.84
Sangay National Park (this study)	3,400 m	0	N/A	10	0.75
Sangay National Park (this study)	2,962-3,400 m	4	0.50	15	0.88

(Lee et al. 2010). However, only four species at Santa Rosa were cricetids (Lee et al. 2010), whereas all eight species at Parque Nacional Sangay were cricetids. Therefore, as elevation increases there are fewer flying insects and fewer trees with fruit suitable for bats, whereas the páramo is dominated by grasses which granivore rodents can use to their advantage. Our data do show a peak in diversity in a mid-elevation range for cricetids, which also was found among non-volant mammals in a study by McCain (2005).

In 2001, a study was conducted near the northern border of Parque Nacional Sangay at a lower elevation than this study (1,700 m to 2,700 m) (Haynie et al. 2006). In that study, 15 species were collected, but only three taxa (*Akodon mollis*, *Microrhizomys minutus*, and *Thomasomys paramorum*) were found in common

with our study (Haynie et al. 2006). In contrast, at the geographically more distant Papallacta, but at an elevation similar to our study sites, Voss (2003) recorded seven species in common with our study. The difference in elevation between our study and Haynie et al. (2006) is perhaps the reason for the dissimilar species composition between the two study areas despite their geographic proximity.

Cytochrome-*b* sequence analysis indicates that a specimen identified morphologically as *T. baeops* (by many researchers) from this study was not most similar to other previously identified *T. baeops* (Fig. 2), suggesting that *T. baeops* may not be monophyletic. Our results suggest the need for a more thoroughly sampled phylogenetic analysis of the genus *Thomasomys*. Furthermore, cytochrome-*b* analysis confirmed the

presence of *T. praetor* in Ecuador; we did not collect any confirmed specimens of *T. aureus*. Additional specimens of *T. praetor* will be needed in order to test the taxonomic limits of this species group.

The presence of potentially unrecognized species as well as pristine areas within Parque Nacional Sangay provides an impetus for conservation efforts. However, there are some current threats to the area, such as the highway that passes by the Atillo Lagoons. The Guamote-Macas highway is under construction to ex-

pand and improve the existing road, and it is proposed to become the major east-west corridor in southern Ecuador, despite the fact that the highway improvement project is a violation of international treaty because Parque Nacional Sangay is a UNESCO world heritage site. Road construction is a known cause of increased disturbance in other Ecuadorean natural areas, and the concern is that species in Parque Nacional Sangay similarly will suffer from increased human pressure in the near future (Finer et al. 2009).

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